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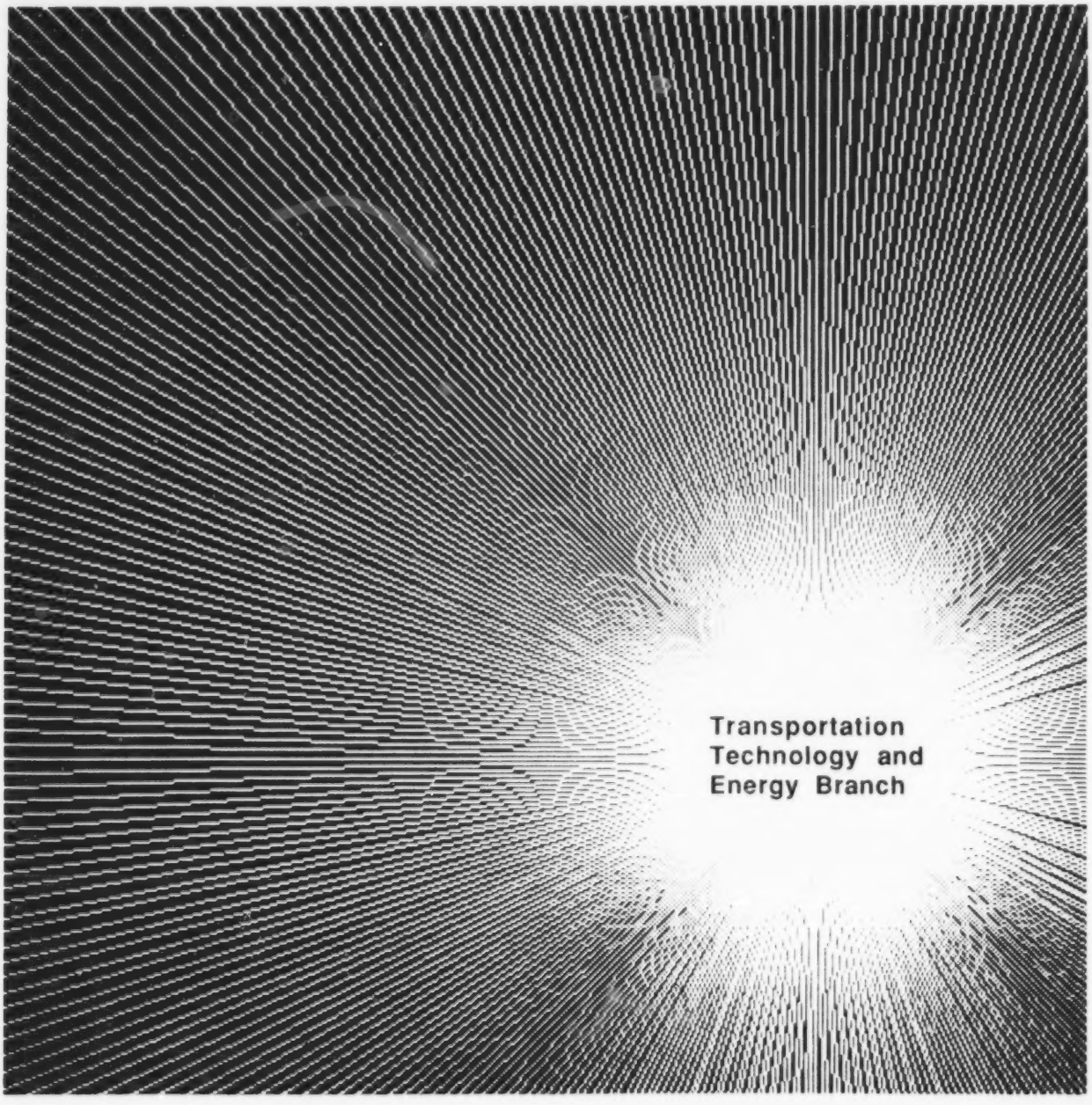

A Review of the Provincial Transportation Impacts of the Canadian Management Plan for NO_x/VOCs: Ontario Perspective

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A Review of the Provincial Transportation Impacts of the Canadian Management Plan for NO_x/VOCs: Ontario Perspective

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SUMMARY

The Canadian Council of Ministers of the Environment (CCME) requested in October 1988, that a management plan be developed for the control of nitrogen oxides (NO_x) and volatile organic compounds (VOCs). The plan, which was developed in recognition of NO_x and VOCs related health and environmental concerns, was to be delivered to CCME by October 1990. The draft plan was issued in March 1990. The impacts of the recommendations in the plan are discussed in this paper.

In the plan, it is recognized that the transportation sector is a significant source for VOCs and NO_x. In 1985, in Canada, transportation accounted for about 62% of total NO_x emissions and 40% of total VOCs. Of this total, passenger cars and light-duty trucks contributed 24% of the total NO_x and 30% of total VOCs. The plan indicates that the total emissions from transportation can be lowered by a combination of structural and life-style changes.

In the paper the benefits and costs of implementing structural changes such as new emission standards for both light and heavy-duty vehicles are reviewed. In addition, means for controlling the emissions of in-service vehicles are explored. Finally, the effectiveness of implementing urban transportation management plans, and the impact of altering our lifestyle by introducing restricted activity days and stricter enforcement of speed limits is discussed.

1/ INTRODUCTION

The Ministry of Transportation of Ontario (MTO) has the responsibility to plan, provide and manage a diverse range of mobility services within Ontario. These services provide transportation for people and freight on land, sea, and air and are fundamental to the standard of living enjoyed by Ontario residents. To ensure mobility, the Ministry builds and maintains highways, manages the traffic on them, and funds municipal roads, transit, and GO Transit through transfer payments. Ferry services are provided to a few islands and the construction of airports is funded to provide access to remote sites or to improve the economic competitiveness of a region. In addition to providing these services, the Ministry regulates the length and weight of vehicles on roads, issues driver licences, registers vehicles, performs vehicle safety inspections and conducts research, development, and demonstrations in support of the above activities. The Ministry also makes recommendations to Transport Canada, which is responsible for aviation, rail, and marine transportation.

Over the years, transportation services have been provided by the Ministry with due consideration to safety, efficiency, economics, and the environment. However, as public expectations have been altered with time, the relative importance of these factors has changed. As we enter the 90s, the need to protect and preserve our environment is becoming one of the main issues confronting Canada and the world. At a local level, air and water quality are a major concern; on a global scale, the issue of global warming has been thrust upon the world as a new challenge to address. However, these issues are only components of the larger issue of sustainable development. Consequently, to address these environmental issues at both a local level and on a global scale, the Ministry believes that it is preferable that an overall integrated approach be adopted wherever possible.

With this objective in mind, initiatives are under way within the Ontario government to understand the nature and extent of the environmental issues within the context of sustainable development and global warming. The National Task Force on the Environment and Economy, established by the Canadian Council of Resource and Environment Ministries, recommended the creation of National and Provincial Round Tables on Environment and Economy. Ontario established such a round table to look at the issue of sustainable development and to bring together senior decision makers from all sectors to cooperate on environment/economy integration strategies and to influence planning. Sustainable development embodies the idea of meeting the needs of the present without compromising the ability of future generations to meet their own needs. One element of sustainable development is to reduce the production of pollutants. The Ontario Round Table issued its Challenge paper in July 1990.

In addition, the Ontario government has requested that each ministry conduct a review of its program and operations from the perspective of sustainable development. As part of MTO's strategic management process, it established its own sustainable development task force to conduct the review. This review investigated the

relationship between the environment, the economy, and transportation so that appropriate conservation and alternative opportunities could be identified.

The review established the following key areas to focus on:

- Atmospheric Emissions from Transportation
- Transportation Corridor Water Management
- Transportation Corridor Land Management
- Sustainable Development General

For the atmospheric portion of the study, the emissions of direct concern were hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and carbon dioxide (CO_2). A report on the recommendations of the task force has been issued [1]. For atmospheric emissions, the recommendations highlight the use of conservation, alternatives, modal switching, efficiency improvements, and stricter standards to reduce these emissions.

Recently, the issue of global warming has been added to the list of environmental concerns facing the world. Global warming results from trace gases absorbing and then re-emitting long wavelength radiation emitted from the earth's surface. The effect of this is to warm the atmosphere. The trace gases of primary concern are carbon dioxide (CO_2), methane (CH_4), CFC-11, CFC-12, and nitrous oxide (N_2O). The combustion of fuel in engines results in the emission of some of these gases. In addition, water vapour and ozone are known to be powerful global warming gases. Water vapour is usually not mentioned because it is not a manmade gas and is principally affected by temperature. The influence of ozone on global warming is difficult to measure because it has a very short life and is typically concentrated over industrialized areas. The global warming issue is currently being addressed by the United Nations (UN) to see if a common target for the reduction of these emissions can be developed for the world.

To meet the challenge posed by global warming, MTO has established a global warming committee to determine how it can address this issue by reviewing its operations, by influencing the users of the transportation system, and by seeking new standards. The activities of this task force are being coordinated by the Transportation Technology and Energy Branch.

As can be seen, common themes are to be found among the issues of sustainable development and global warming. The management plan for nitrogen oxides (NO_x) and volatile organic compounds (VOCs) was developed to address health and environmental concerns associated with NO_x and VOCs. These chemicals are precursors for the formation of ozone (O_3), a chemical which at low concentration causes air quality to deteriorate. Also, NO_x contributes to formation of acid rain and some of the VOCs are toxic. An understanding of the strong interrelationship between

all of these issues is essential and a comprehensive strategy which addresses and balances all three issues should be put in place.

There are two basic ways to address these issues. We can undertake to have structural changes made which will make the equipment we use more efficient. In addition to this, we can attempt to change our lifestyle by reducing demand and conserving. Surveys of the public indicate that people are willing to pay up front for structural changes, i.e., stricter emission standards on cars. However, the same polls indicate that they are not as willing to make significant changes to their lifestyle, i.e., use public transit rather than a private car. This paper looks at the recommendations of the NO_x/VOCs report in the context of structural changes and lifestyle changes and presents some of the possible impacts.

2/ Standards Setting

Canada and the U.S. share a common border through which many products pass. The ability to move these products across the border is simplified by the use of common standards. The setting of these standards is agreed upon after a mutual understanding of the issues and the needs is reached. Currently, Canada and the U.S. have similar emission standards for automobiles and diesel engines. At the present time, new standards for cars and light-duty trucks and diesel engines are being proposed for introduction in Canada in 1994, and it is anticipated that they will be similar to those in the U.S. This consistency has certain economic benefits for Canada.

In the U.S., the emission standards for cars and diesel engines, along with standards for other industries, are being set so that the one-hour average ozone concentration of 120 parts per billion will be exceeded no more than once per year [2]. However, comparing the ozone standard for Canada with the U.S. standard, Canada has set a target that is 33% stricter than that set in the U.S.

	Canada	U.S.
Ozone	<82ppb	<120ppb

The lower levels mean that longer exposure times can be tolerated. At a level of 80ppb, a construction worker could work for seven hours with few adverse effects likely. This time is reduced to five hours at 120ppb. Studies have shown that strenuous activity for more than two hours in ozone levels above 120ppb could result in adverse effects such as temporary loss of some lung function [2].

While it is recognized that having lower ozone concentrations is better for health, Canada should consider setting, for some areas, an interim intermediate standard that accounts for the incoming higher concentration of pollutants from the U.S. While an ozone concentration of less than 82ppb may be an appropriate standard for most of

the country, an interim intermediate standard should be considered for areas bordering the U.S.

This may be particularly important for southeastern Ontario which borders non-attainment areas in the U.S. exceeding ozone levels of 120ppb. Since it is recognized that peak ozone levels in southeastern Ontario and along Lake Erie and Lake Huron are due almost entirely to U.S. emissions, it will be almost impossible to achieve an ozone value of less than 82ppb in this area, when the cross border atmospheric flows contain ozone concentrations above 120ppb. The management plan recognizes the impact of major U.S. border emission sources on ozone and its precursors on southeastern Ontario [3].

The setting of interim intermediate less stringent standards for some areas does not mean that we should diminish our resolve to improve the air quality, it is simply a recognition of the difficulty of the challenge. For these areas, achieving the intermediate level would be a milestone.

3/ Vehicle Related Recommendations

In the plan, it is recognized that the transportation sector is a significant source for VOCs and NO_x. This sector includes cars, light and heavy-duty trucks, rail, and off-road vehicles used in construction and agriculture. In 1985, in Canada, transportation accounted for approximately 62% of total NO_x emissions and 40% of total VOCs. The sector contributions to NO_x and VOCs are shown in Figures 1 and 2.

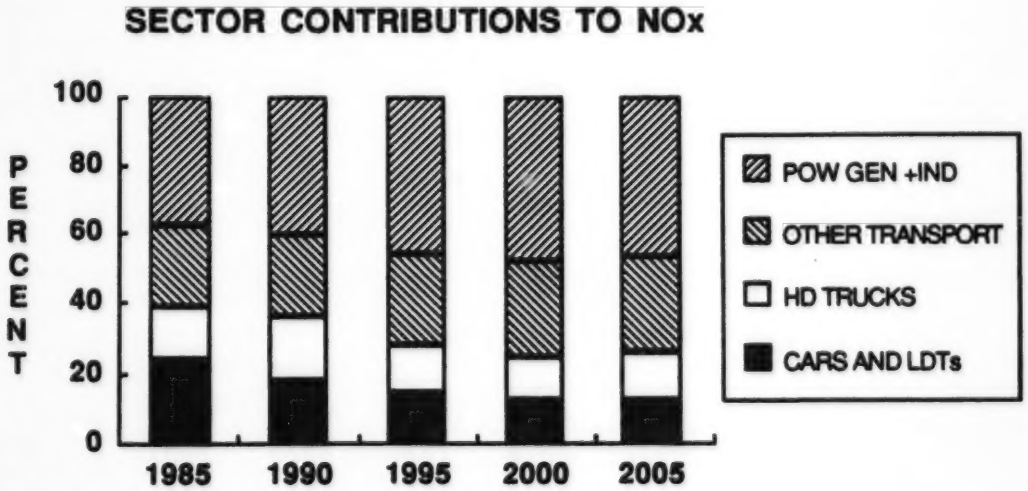

Figure 1: Projected Sector Emissions to NO_x

The NO_x emissions are generated by passenger cars, light-duty trucks, heavy-duty vehicles, trains, and off-road vehicles. The contribution of the light-duty vehicles, in

1985, to NO_x is 24% of the total or 38% of the transportation component. The VOCs come primarily from cars and light-duty trucks and off-road gasoline vehicles. The VOCs are emitted as unburnt hydrocarbons in the car exhaust and as evaporative losses from the vehicle fuel system. These evaporative losses can be equal to or greater than the tailpipe VOCs emissions on hot days. As shown in Figure 2, cars and light-duty trucks contributed 30% of total VOCs or 74% of the transportation component, in 1985.

To decrease the production of these emissions, the management plan for NO_x/VOCs recommends the introduction of stricter emission standards for new passenger cars and light-duty trucks and diesel engines, and a program to inspect and maintain in-service vehicles. The impacts of these recommendations are discussed below.

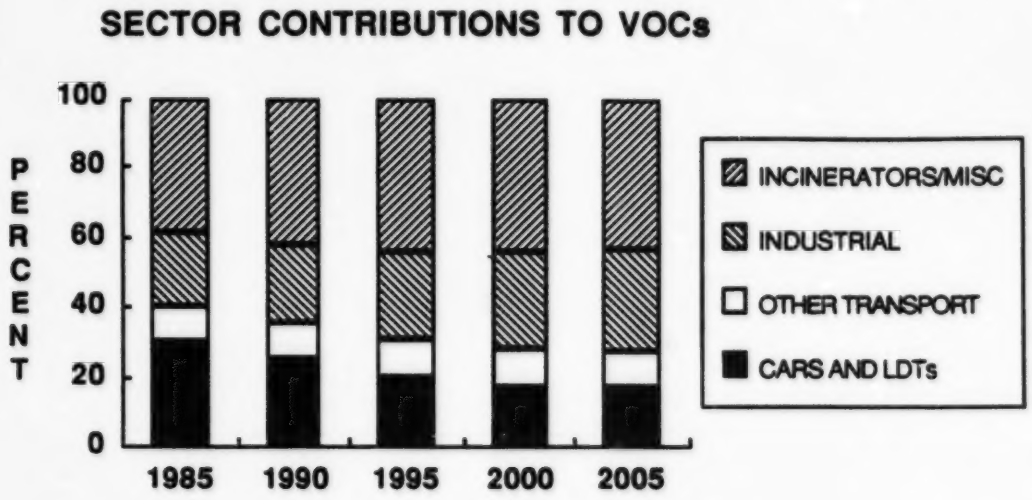

Figure 2: Projected Sector Emissions to VOCs

3.1/ Light-Duty Vehicle Emission Standards

To control the emissions from new light-duty vehicles, the management plan for NO_x/VOCs recommends the introduction of stricter emission standards for passenger cars and light-duty trucks. Recommendation N301 sets a NO_x standard of 0.40 g/mile no later than 1996, and V301 sets a 0.25 g/mile standard for hydrocarbons. Ontario is supporting the introduction of stricter emission standards for light-duty vehicles in Canada, beginning in 1994. The proposed 1994 car emission standard specifies a level for carbon monoxide, in addition to those set for NO_x and HC (VOCs). The 1975-1987 passenger car emission standard, the current standard, and the proposed 1994 standard are listed in Table 1 for comparison purposes. The proposed 1994 standard is very similar to the standard proposed for California and the rest of the U.S.

As can be seen, the current standard is significantly stricter than the one in force prior to 1987. This standard is 68% stricter for NO_x and 81% stricter for VOCs than the pre-88 standard. This 1987 standard, which will be effective until 1994, will help to reduce the levels of NO_x and VOCs emitted by the vehicle fleet in the 90s as older vehicles are scrapped and replaced by new ones. The newer standards for 1994 will continue this trend. To meet the proposed stricter 1994 standards, gasoline fuel metering systems will have to be designed to more accurately meter the fuel to the engine, the efficiency of the three-way catalyst will have to be increased, more reliable ignition systems will be added, and more accurate measurement systems will be developed. It should be noted that while the 1994 standard was set for cars, it will also apply to light-duty trucks weighing less than 1700 kg (3750 lbs). It is expected that this will be a difficult standard to meet for these higher weight vehicles.

	1975-1987	Current	Proposed 1994
Hydrocarbons (g/mi)	2.0	0.41	0.25*
Carbon Monoxide (g/mi)	25.0	3.40	3.40
Nitrogen Oxides (g/mi)	3.1	1.00	0.40

* Non-methane hydrocarbon standard

Table 1: Emission Standards for Cars and Light-Duty trucks

The benefits of the stricter 1987 standards can be seen in Figure 3 which shows the projected quantity of VOCs and NO_x produced annually in Canada until the year 2005. On an absolute basis, it shows that the contribution to VOCs and NO_x emitted from cars and light-duty trucks in Canada decreases significantly from 1985 to the year 2005. The contribution to VOCs drops from 555 kt/yr to 346 kt/yr while the contribution to NO_x goes from 447 kt/yr to 227 kt/yr. The reduction in these pollutants is a direct result of replacing older cars with cars that meet the 1987 standard. The projection also accounts for an increasing vehicle population which starts to change the reducing trend in the year 2000 to an increasing one in 2005. The more stringent 1994 emission standard is expected to achieve a further reduction of 16.3 kt/yr in VOCs and 64.0 kt/yr in NO_x below the 2005 level. While cars and light-duty trucks are reducing their relative emissions between 1985 and 2005, the other sectors will be increasing their relative contributions. This is shown in Figures 1 and 2. A similar situation occurs with VOCs emissions.

It should be noted that the effort to improve the emissions from vehicles cannot be reduced, even though considerable gains are already projected for the car and light-duty truck sector. It must be remembered that there is a significant concentration of vehicles in urban centres and these reductions are necessary to prevent a serious deterioration in air quality in these centres.

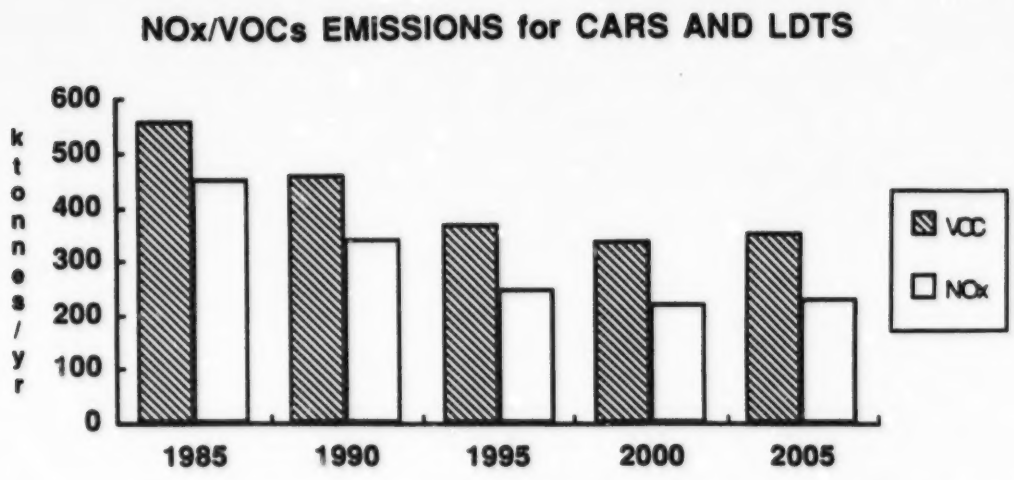

Figure 3: Projected Canadian NO_x/VOCs Emissions for Cars and LDTs

By increasing the current emission standard to the proposed 1994 level, cars and light-duty trucks will further decrease their contribution to VOCs by 4.7% and to NO_x by 28% in 2005. For vehicles to meet the proposed 1994 standard, it is estimated that the additional equipment will add from $250 - $400 to the price of each vehicle. In Ontario, approximately 500 000 new vehicles are sold annually. This translates into an annual incremental cost of $162.5M, assuming an average incremental cost of $325 per vehicle. For all of Canada, it is $422M, for the approximately 1.3M cars and light trucks sold annually today.

While the reduction of VOCs in the year 2005, associated with the introduction of the 1994 emission standard, is not projected to be as great as the reduction from the introduction of the 1987 standard, it should be noted that the catalyst is oxidizing the most reactive hydrocarbon components. Consequently, the reactivity of the tailpipe hydrocarbon species emitted in the future will be relatively lower than the hydrocarbons emitted in 1985. This is an additional factor which should be considered when the impacts of the current and future emissions are estimated.

3.2/ Monitoring Emissions from In-Service Vehicles

The NO_x /VOCs management plan recommendation N601 requires that a periodic inspection program be undertaken to monitor the emissions of in-service vehicles in selected areas such as the Lower Fraser Valley (LFV) and the Windsor-Quebec Corridor (WQC). This is commonly done in some U.S. states and has been quite effective.

An inspection and maintenance program has been in effect in Connecticut since January 1983. In the inspection, the hydrocarbons and carbon monoxide are

measured under hot idle conditions. The test results are compared against the emission standards for that car. Results to 1988 show that the rejection rate is around 11.5%. It is believed that the rejection rate in Canada would be lower because of the lower average age of vehicles. In 1989, the inspection fee was $10 U.S. per car and it required approximately 15 minutes to complete, including time in the line [4].

The monitoring of the emissions of in-service vehicles can be undertaken in a variety of ways. Two ways suggested in the NO_x /VOCs management plan are to implement a periodic inspection and maintenance plan or an inspection on vehicle resale. If such a plan were to be implemented by 1994, as suggested in the recommendation, the cost of these inspections could vary between $15 to $20 per vehicle, based on the 1989 cost in Connecticut. If such a plan were to be implemented on a national scale, this would cost from $225M to $300M annually for the approximately 15 million passenger cars and light-duty trucks currently in use in Canada today. This cost could be cut in half if the vehicles were inspected every two years or further still if confined to the LFV and WQC. Also, the type of test and the method of program delivery affect the cost.

The cost of a monitoring plan based on vehicle inspection on resale would be significantly less than the periodic inspection plan discussed above because the number of vehicles resold annually is somewhere between 10% and 15% of the fleet. Such a plan has merit because of its lower cost and less inconvenience to the public. This has to be balanced against the reduced effectiveness of the plan.

Two additional ways for monitoring vehicle emissions in the future may be possible . A remote sensing device, developed by Dr. D. Stedmann, is capable of measuring the ratio of CO to CO_2 in the exhaust emission of passing cars. As the vehicle passes through the measuring site, an infrared beam is passed through the exhaust and the ratio of CO to CO_2 is recorded. In a properly tuned car, this ratio is within an expected range. When a vehicle is out of tune because it is running too rich, this ratio is increased beyond the expected range. If an out-of-range value is detected, the vehicle can then be sent to an inspection station for a more detailed evaluation.

While the device cannot yet measure NO_x emissions, efforts are being made to develop the appropriate sensor. This device is still under development and further research and evaluations are being conducted on it. Some of the questions associated with using this instrument relate to the conditions under which the measurements should be taken and the triggering levels for non-compliance.

The use of this instrument has much appeal because it is not intrusive to the public and only the few cars with out-of-range readings have to be checked. This certainly reduces overall costs and time lost on the part of the public. In addition, it could potentially be used to provide information on the overall condition of the in-service vehicle fleet and permit projections to be made on emissions.

The cost of using remote sensors depends on the failure rate in the vehicle population and the probability that the vehicle will pass through the detector. Assuming that the failure rate of Canadian cars is 5%, i.e., approximately half of the Connecticut failure rate, and that stations are set up to measure 25% of all vehicles, 187 500 non-compliant vehicles would be detected annually. These vehicles would be checked more thoroughly at a motor vehicle inspection station, and it is estimated that the cost would be in the $50 range rather than the $15-$20 range estimated for the system used in Connecticut. This would amount to an annual cost of $9.4M to the public. Other costs in this program could add an additional $5M to the total cost.

Another way to inspect vehicles in the future would be to incorporate on-board diagnostics on vehicles equipped with feedback control systems. Currently, some late model vehicles have a limited scope to check the on-board electronics and some critical emission-related components. In addition, the electronics has limited ability to compensate for the wear and drift in the fuel metering components. This compensation is necessary to maintain accurate control of the fuel/air ratio throughout the life of the vehicle.

In California, it is now being proposed that this checking capability be extended to include all of the components which are part of the emission control equipment. It is proposed that on-board diagnostic (OBD) systems be installed on 1994 and later passenger cars and light trucks to monitor the functioning of the catalyst, engine misfire, canister purge system, exhaust gas recirculating valve, and the secondary air system. As an example, in this system, the catalyst efficiency would be monitored continuously and the vehicle would fail when the catalyst efficiency fell below 50%. If the computer were to detect a component failure, it would signal the driver that a failure has occurred and corrective action would be expected. The failure would also be recorded in the on-board computer. As these OBD systems enter the fleet, it may be feasible to replace the current California inspection and maintenance program by having a computer interrogate the diagnostic system for the presence of stored fault codes. Similar actions could be taken in other jurisdictions with inspection and maintenance programs.

The cost of adding an OBD system to a vehicle is expected to be around $100. Over an average vehicle lifetime of ten years, this is equivalent to an annualized payment of $13 per year at a real discount rate of 5%. Such a system would pose minimal inconvenience to the public, while at the same time minimizing the impact of vehicle emissions on air quality. If OBD systems were installed on all new cars and light trucks sold in Canada in 1996 and later, the incremental cost would be $130M annually for the approximately 1.3 million passenger cars and light-duty trucks sold annually.

The management plan has estimated the benefits of maintaining vehicles close to the emission specifications throughout their lifespans without specifying the method. The estimate was based on U.S. data and took into account Canada's different yearly

average temperature and the age of the vehicle fleet. The reduction to VOCs and NO_x was estimated to be 16% and 4% respectively. In the year 2005 this will amount to 52 kt/yr of VOCs and 9 kt/yr of NO_x.

3.3/ Heavy-Duty Vehicle Emission Standards

In the management plan, recommendation N302 requires that new heavy-duty engines meet a 5.0 g/bhp-hr NO_x emission standard for 1994. This requirement is similar to the U.S. Environmental Protection Agency (EPA) standard regulating the emissions for diesel engines in the U.S and also being considered for Canada. The EPA standard initially came into effect in 1989 and becomes more stringent in 1991 and 1994. The standard also distinguishes between emissions for diesel engines used in transit buses and in heavy-duty trucks. However, in 1994 the truck and bus emission standard will be identical. For diesels, the standards for HC and CO were set at 1.3 and 15.5 g/bhp-hr respectively and do not change with time. However, the standards for NO_x and particulates become increasingly stricter with time as shown in Figure 4. The truck standard for particulates drops from 0.25 g/bhp-hr in 1991 to 0.1 g/bhp-hr in 1994. As can be seen in the illustration below, the greatest reductions are to be achieved in particulates. Particulates are controlled because studies have indicated that they are carriers of carcinogens into the lungs.

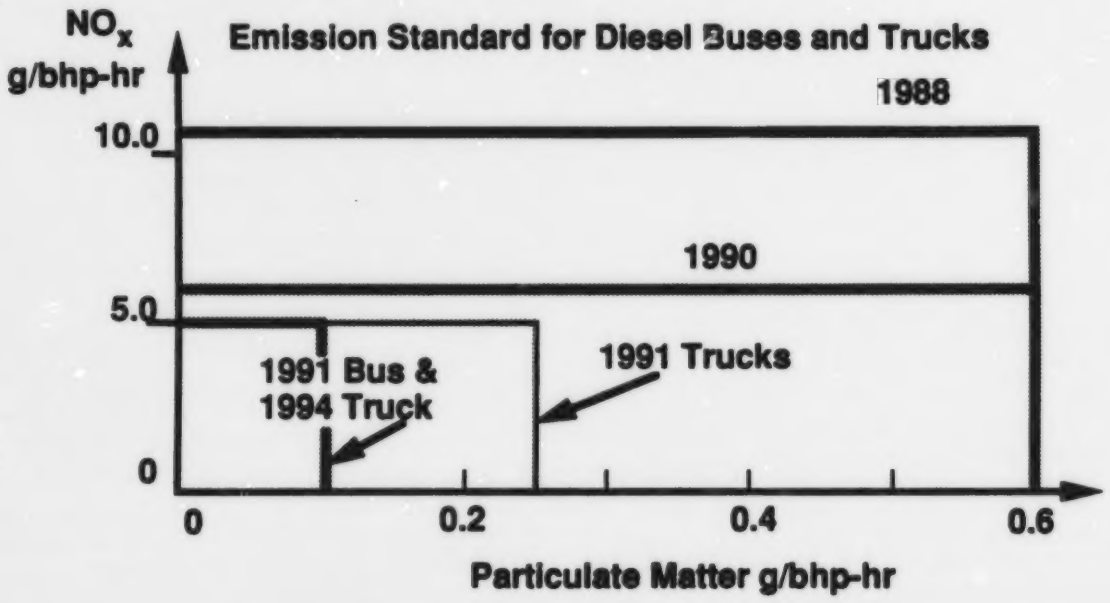

Figure 4: Emission Standard for Diesel Buses and Trucks (U.S.)

To meet these emission standards, governments and industry investigated two approaches. One approach was to use particulate traps and the other was to use alternative fuels. The approaches were different in that the trap would capture the

particulate matter produced by the diesel fuel and then burn it off. On the other hand, it was known that the combustion of alternative fuels produced extremely low levels of particulates and that the standard could be met without a trap. To meet the standard with alternative fuels, it was thought that an automotive type catalyst would be required to meet the proposed standard for HC, NO_x, and CO.

It is difficult to determine how diesel emission reduction costs associated with NO_x and particulates respectively should be allocated. Systems have been developed to control the production of NO_x and particulates in the engine. However, changes to improve one emission can make the other worse. For instance, decreasing the combustion temperature to decrease NO_x formation causes an increase in the production of particulates. This is a reasonable strategy to follow for the engine manufacturer because the particulates can be removed from the exhaust using a particulate trap. The cost of the trap for a bus or a heavy truck is expected to be around $10,000. Attributing an estimated cost of 10% of this, or $1000, for the reduction in NO_x, this would amount to an annual cost of $25M for the approximately 25 000 heavy-duty diesels sold annually in Canada. Diesel fuel will have to be refined to reduce sulphur content and to permit diesel engines to meet the particulate standard. However, this cost cannot be attributed to the NO_x/VOCs plan.

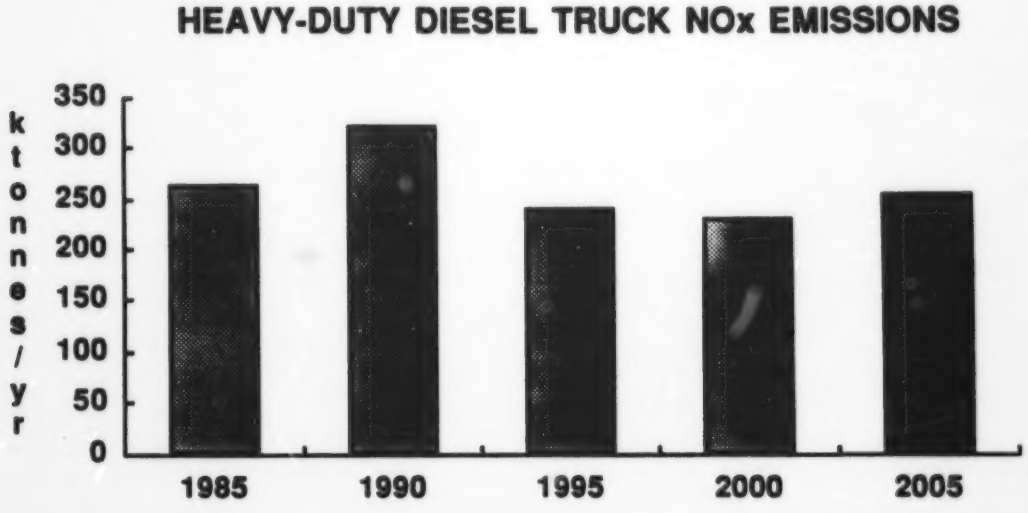

Figure 5: Projected Canadian NO_x Emissions for HD Diesel Trucks

Significant reductions to NO_x emissions from heavy-duty vehicles can be achieved by introducing a stricter standard for diesel engines in 1994. As shown in Figure 5, the introduction of the 1994 standard will reduce the production of NO_x from 322 kt/yr in 1990 to 254 kt/yr in 2005, i.e., a reduction of 68 kt/yr. This is a 21% reduction in NO_x from current levels. The management plan indicates that a reduction of approximately 21 kt/yr will occur from 1985 to 2005. However, in the period from 1985 to 1990, a

significant expansion of the fleet causes the total NO_x emissions from diesels to increase from 264 kt/yr to 322 kt/yr. The benefits of implementing the stricter standard is seriously underestimated by using 1985 as a base.

Another way to meet the new emission standards for heavy-duty vehicles is to use alternative fuels. The potential fuels for this market are methanol, natural gas, and propane. The use and evaluation of these fuels in heavy commercial vehicles is just beginning and much remains to be learned [5,6]. The greatest experience to date has been obtained with the use of methanol and natural gas in buses [7]. A precise estimate for the costs and benefits of the use of these fuels in both the light and heavy-duty vehicle markets will have to await further research and development.

4/ Rail Transportation

The management plan initiative N304 recommends that a cap be set on NO_x emissions from the Canadian rail transport system at 115 kt/yr, effective 1992. In the future, this cap could become an impediment to potential modal shifts in freight transportation. In recent years, trucking has been transporting more freight as the need for just-in-time delivery increased. However, as mentioned above, the world is now trying to deal with the issue of global warming. One of the proposals being put forth at this time to reduce global warming is to reduce the production of carbon dioxide (CO_2) to 20% below the 1989 levels by the year 2005. This is being proposed because the contribution of CO_2 to global warming is 50%.

Studies have shown that on the basis of fuel per tonne-km, the railroads are approximately 2.5 to 3.0 times more energy-efficient than trucks [8]. If one of the ways to reduce the production of CO_2 is to transfer freight back to the railroads, they could be limited by the NO_x cap suggested in N304. Rather than having a cap, it is suggested that a standardized test cycle be developed which would rate the emissions of a railway diesel engine on a gm/bhp-hr basis. This would then not penalize the rail system for the extra load which might reappear from the trucking sector. This could potentially reduce production of NO_x and one of its components, nitrous oxide, which contributes 6% to global warming. A standard based on emissions per unit of work would be more appropriate than a cap. Also, such a standard could be more readily monitored at the manufacturer's level.

5/ Urban Transportation Management Plan

Initiatives N401 and V401 propose urban transportation management plans designed to reduce NO_x and VOCs emissions in all urban centres in the LFV and WQC with population greater than 200 000 by 1992. The premise is that substantial NO_x and VOC emissions reduction can be achieved by improving urban transportation efficiency for people and goods. It is suggested that provincial governments now coordinate the development of the management plans and provide new incentives for

their implementation. The need is emphasized to estimate emission reductions achieved through implementation of the plans.

The initiatives are appropriate in that they reflect the significance of the contribution to NO_x and VOCs emissions by urban transportation. In refraining from setting specific targets, they also permit flexibility in that they reflect the complexity of the problem, the multiplicity of possible components of the plans, the degree of uncertainty surrounding their efficiency, and the need for the developed plans to be based on cost-effective measures. To the extent possible, the NO_x/VOCs reductions per dollar invested should be estimated. The measures should be ranked in terms of cost-effectiveness and, indeed, compared to the cost-effectiveness of other transportation initiatives in the overall NO_x/VOCs management plan.

The Ministry of Transportation of Ontario (MTO) recognizes the importance of urban transportation management and its contribution to reduced transportation emissions. MTO has recently announced a $5 billion transit implementation program in the Greater Toronto Area, to meet transportation needs and to reduce emissions damaging to health and to the environment. MTO has also actively promoted energy conservation, energy efficiency, and programs to achieve reduced vehicle-kilometres of travel, such as ridesharing, and staggered and flexible hours.

After considering the amount of work that has to be accomplished to develop these urban transportation management plans, it is believed that June 30, 1992 may be too early to complete development of such management plans. In addition, the development of these plans is the responsibility of the municipalities and a significant amount of consultation would be required between the two levels of government. This will add to the time required to develop the plan.

The impacts are uncertain until the plans are developed and cost-effectiveness and priorities established. Transportation efficiency is seen as the primary generator of emission reductions and, to a large degree, the double objectives of efficiency and emission reduction are complementary and mutually supportive. This is not necessarily the case, however. If, for example, improved road transport efficiency leads to secondary effects such as dispersed land-use development or a shift from transit to cars, emissions may rise. A major challenge is maintaining and increasing transit's share of travel, and reducing vehicle-kilometres of travel.

Given the federal government's interest and initiative in the NO_x/VOCs management plan, it would appear reasonable to expect the federal government also to participate in incentives to ensure implementation of the urban transportation management plans.

6/ Speed Limit Enforcement

Initiative N502 proposes more effective speed limit enforcement and/or lower speed limits to achieve at least a 10 km/hr reduction in average speed of heavy-duty vehicles on major highways in summer by 1993 in the LFV and WQC.

One of the impacts of enforcing this recommendation would be the requirement for significant increases in enforcement personnel, an increase that would seem unlikely in view of current funding limitations. This problem is further aggravated if speed limits are to be lowered. Controlling speeds to current limits is already difficult. This will not be popular, as there is already public demand for higher speed limits. If the existing or lower speeds cannot be effectively enforced, lower speed limits may be counter-productive, encouraging massive disregard of the limits.

Safety is generally improved if road speeds tend to be uniform. Differential speed limits for different vehicle classes may have adverse safety consequences. Public education of drivers of all vehicle classes may be the most effective way of achieving the desired results, as proposed in initiative N503.

7/ Restricted Activity Day

Initiatives N501 and V501 propose that "restricted activity day" programs be put in place in all urban centres over 500 000 by 1993 in the LFV and WQC. These would be implemented with actions in three categories depending on the forecast severity of the air quality condition. Category I measures would be mostly voluntary; Category II and III measures would be mandatory, such as staggered or noon start of work day, disincentives for private vehicle use, especially in downtown areas, and prohibition of single-occupant vehicles on freeways. The plans would become effective for the summer of 1993.

The effectiveness of this plan is uncertain and will clearly depend on the plan. One advantage of such plans is that they are put into effect only when necessary. Under severe forecast conditions, impacts and disruption to normal business and commuting could be substantial, particularly if Category II and III measures are frequently triggered. Significant dissatisfaction may result where local activities must be restricted due largely to emissions coming in from the United States.

8/ Summary and Impacts of Plan Recommendations

A summary of the costs and emission reduction benefits for some of the transportation-related recommendations is given in Table 2. The emission reduction for each recommendation was obtained from the management plan [3], while the costs are independent estimates which differ from those in the plan. Since the difference in the two estimates are so large, a further review and refinement of the plan costs are

warranted. For comparative purposes, the plan figures are given in brackets. In all cases, the estimate represents the total cost for both NO_x and VOCs.

Table 2: Cost and Emission Reduction of Recommendations

Measure		Year 2005 Emission Reduction (kt/yr)	Additional Cost* ($)
1987	Emission Standard	NO_x 220 VOC 209	Already in plan
N301 V301	1994 light-duty Vehicle Emission Standards	64.0 16.3	422 M/yr in 1994 (185 M/yr in 2005)
N302	Heavy-Duty Vehicle Emission Standards	20.9**	25 M/yr in 1994 (0.8 M/yr in 2005)
N304	Rail Transportation Cap on NO_x	NE***	NE
N401 V401	Urban Transportation Management Plan	NE NE	NE NE
N501 V501	Restricted Activity Day	NE NE	NE NE
N502	Truck Speed Limit Enforcement	5.1	NE
N601 V601	Vehicle Emission Inspection Programs	9.0 52.0	- 225-300 M/yr for major pgm. - 130 M/yr using OBD - 10-15 M/yr using remote means (107.4 M/yr in 2005)

* Total cost for both NO_x and VOCs
** See page 11
*** No Estimate

9/ CONCLUSIONS

1. The management plan is in many respects a good approach for achieving reductions in NO_x and VOCs emissions in Canada.

2. The Canadian standard of 82 ppb should be reviewed relative to the U.S. standard of 120 ppb. Higher interim, intermediate standards should be set for areas near the U.S. border where U.S. emissions are carried into Canada, making the Canadian standard difficult to achieve.

3. The management plan shows that major reductions to NO_x and VOCs emissions can be achieved through structural and lifestyle changes.

4. One of the most significant structural changes was made in 1987 when stricter emission standards for cars and light trucks were introduced. The data show that cars and light-duty trucks will be making significant progress in reducing their emissions from 1985 to 2005, both in absolute terms and as a proportion of total emissions. Over this period, in absolute terms, NO_x will be reduced from 447 kt/yr to 227 kt/yr (49%) and VOCs from 555 kt/yr to 346 kt/yr (38%). Over this same period, as a proportion of total emissions, the cars and light-duty truck contribution to NO_x will be reduced by 50% and to VOCs by 43% from the 1985 levels. The introduction of stricter standards in 1994 will further reduce these contributions to VOCs by 5% and to NO_x by 25% relative to the 2005 levels. The current reductions, along with those projected for the 1994 standards, apparently will dwarf any of the other transportation measures in the plan.

5. Significant reductions to emissions from heavy-duty vehicles can be achieved by introducing stricter standards for diesel engines in 1994. The introduction of these 1994 standards will reduce the production of NO_x from 322 kt/yr in 1990 to 254 kt/yr in 2005. This is a 21% reduction in NO_x from current levels.

6. Vehicle inspection programs also effect significant reductions, especially for VOCs. Major inspection programs are costly and may be superseded by mandatory on-board diagnostics equipment or less costly remote testing techniques.

7. Urban transportation management plans would appear to be an important component in emission reduction, though not yet quantified regarding cost or effectiveness. Ontario supported and continues to support public transit for many transportation and environmental reasons, and has recently announced a $5 billion program. The challenge will be retaining and attracting transit riders, to reduce auto vehicle-kilometres of travel.

8. Restricted activity days need further investigation regarding cost-effectiveness, including impact on the economy and on the public. Such plans appear to have both strengths and weaknesses.

9. Speed limit enforcement for heavy trucks and/or lower speed limits in summer appear to achieve only modest reductions in NO_x. Significant enforcement personnel increases would be required and this is unlikely to be achieved. Lower speed limits, while beneficial, would be quite unpopular. Differential speeds for different vehicle classes would also raise some safety concerns.

10. The challenge for other sectors will be to match the improvements being made in the transportation sector.

References

1) *Sustainable Development and the Implications to the Ministry of Transportation*, MTO Sustainable Development Task Group Report, April 1990.

2) *Catching Our Breath*, Summary, Congress of the United States, Office of Technology Assessment.

3) *Management Plan for Nitrogen Oxides and Volatile Organic Compounds*, Federal/Provincial Long Range Transport of Air Pollutants Steering Committee, March 1990.

4) Jain, Rajendra, *Air Quality Improvement Through the Vehicle Inspection Program in Connecticut*, Transportation Research Paper 890255, Transportation Research Board, January 1990.

5) Turner, J., T. Topaloglu, and G. Hrynyk, *Development and Demonstration of a Class 8 Propane-Powered Truck*, SAE paper 901499, August 1990.

6) Goetz, W., D. Petherick, and T. Topaloglu, *Performance and Emissions of Propane, Natural Gas and Methanol Fuelled Bus Engines*, SAE Paper 880494.

7) Harmelink, M.D. and O.M.S. Colavincenzo, *The Development of Natural Gas Buses in Ontario*, Ontario Ministry of Transportation, Transportation Technology and Energy Branch, March 1990.

8) Riley, J. H., *Start Now to Stop Big Rigs*, Progressive Railroading, July 1990.